PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P015560WO MJH	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB 03/05094	International filing date *(day/month/year)* 24.11.2003	Priority date *(day/month/year)* 25.11.2002
International Patent Classification (IPC) or both national classification and IPC G01V3/12		
Applicant OHM LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
25.06.2004	23.03.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Juárez Colera, M Telephone No. +49 89 2399-2482

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB 03/05094

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-5, 10-31	as originally filed
6-9, 32	received on 08.03.2005 with letter of 04.03.2005

Claims, Numbers

1-24	received on 08.03.2005 with letter of 04.03.2005

Drawings, Sheets

1/10-10/10	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees, the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☒ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-24
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-24
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-24
	No:	Claims	

2. Citations and explanations

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Prior art

Reference is made to the following document:

D1: WO 01/20366 A (EXXONMOBIL UPSTREAM RES CO) 22 March 2001 (2001-03-22)

2 Article 33 (1), (2) and 3 PCT (Novelty and Inventive Step)

2.1 The document D1 is considered to represent the most relevant state of the art. In particular this document discloses (cf. abstract; p.8, l. 1-19 and p. 14, l. 3 - p. 15, l. 2) an electromagnetic survey method for surveying an area thought or known to contain a subterranean hydrocarbon reservoir, the method comprising: transmitting an electromagnetic signal from a source location, detecting a corresponding response signal at a detector location and obtaining survey data comprising phase values of first and second directions of the received signal.

2.2 The subject matter of amended claims 1 and 12 differs from that of D1 in that it includes calculating the phase differences from the first and second components of the detector signal.

2.3 With respect to the subject matter of amended claim 21, it is considered that the features of creating a model including depth values of a postulated hydrocarbon reservoir of an area to be surveyed and performing a simulation of an electromagnetic survey in the model corresponds to the standard practice in the art (see, e.g. D1, pg. 17, l. 18-21).

2.4 The subject matter of amended claim 21 differs from the known techniques is that the simulated survey includes obtaining from the model the phase differences between the receiver signal components.

2.5 The subject matter of amended claims 1, 12 and 21 is therefore new.

2.6 The problem to be solved by the present invention may be regarded as obtaining from the survey, or deriving from the model, a parameter that indicates more accurately, the presence or absence of hydrocarbons.

2.7 The solution to this problem proposed in amended claims 1, 12 and 21 of the present application is considered as involving an inventive step (Article 33(3) PCT) since it is neither known from, nor rendered obvious by, the available prior art.

2.8 Amended claims 20 and 24 relate to the computer programs corresponding to the methods defined in amended claims 12 and 21 and amended claims 2-11, 13-19 and 22-23 are dependent on amended claims 1, 12 and 21 respectively. All these claims as such also meet the requirements of the PCT with respect to novelty and inventive step.

3 Article 33 (1) and (4) PCT (Industrial Applicability)

The subject matter of amended claims 1-12 is susceptible of industrial application.

Re Item VI

Certain documents cited

The attention of the applicant is drawn to the relevance of the document: GB-A-2 382 875 (MACGREGOR LUCY MARGARET ; UNIV SOUTHAMPTON (GB)) 11 June 2003 (2003-06-11) with respect to the subject matter of all the claims

Re Item VIII

Certain observations on the international application

1 Objections under Article 6 PCT (Clarity)

1.1 Although amended claims 1 and 12 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection

is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.
Moreover, amended claim 12 comprises all the features of amended claim 1 and is therefore not appropriately formulated as a claim dependent on the latter (Rule 6.4 PCT).

1.2 The term "metric" as used in the expression "determining a metric" in amended claim 12 is not clear in the context of the claim. According to the Chamber dictionary "metric" is indeed an adjective and therefore not suitable to be "determined". The use of this term renders the subject matter of the claim unclear.

and the detectors themselves must also be carefully accurately arranged. The difficulties in controlling both the position and the orientation of a towed source antenna, coupled with this need to accurately follow a particular tow path relative to the detector grid, is one of the major sources of error in surveys of these kind. The disadvantages associated with the survey constraints imposed by the Sinha method are the price to pay for resolving the ambiguities inherent in the Statoil method.

A survey having an array of multicomponent receivers has been proposed in which the multiple components provide data redundancy [14].

A survey in which phase data from receivers at different distances from a transmitter are compared to measure geometric spreading has also been proposed [15].

SUMMARY OF THE INVENTION

According to the invention there is provided an electromagnetic survey method for surveying an area that is thought or is known to contain a subterranean hydrocarbon reservoir, comprising: transmitting a source electromagnetic signal from a source location; detecting a detector signal at a detector location in response thereto; obtaining survey data indicative of phase difference between first and second components of the detector signal resolved along first and second directions respectively; and forming the phase difference between the first and second components.

By comparing phase measurements of different components of the detector signal, a phase separation anomaly can be detected which is sensitive to the presence of a hydrocarbon layer or reservoir within a subterranean strata configuration. The presence or not a phase separation anomaly, and hence the presence or not of a hydrocarbon layer, can be determined with a single source orientation. There is no need, as there is with known methods based on amplitude, for data to be collected with different source orientations. Accordingly, surveys can be performed more quickly and without needing to accurately control the source orientation. Furthermore, because of this insensitivity of a phase measurement to the relative source orientation, reliable data collection is not limited to specific source location and detector location geometries, as is the case when collecting in-line/broadside amplitude data, and a much less complex and geometrically restrained towpath can be employed to survey an extended area.

The first and second components can be any two of radial, vertical and azimuthal (with reference to the source location-detector location geometry). The clearest phase anomaly appears to occur from the pairing of radial and azimuthal components. It is also possible to use all three components together, i.e. to have first, second and third components.

The first, second and, if used, third directions are preferably orthogonal, since by observing geometrically independent components of the detector signals, there is

minimal cross-talk between the first and second data sets, and the sensitivity to the presence of a hydrocarbon reservoir is accordingly increased.

The source electromagnetic signal can be broadcast from an antenna mounted on a submersible vehicle, or from a static location, such as within a borehole, or from an oil or gas platform.

The source electromagnetic signal can be emitted at different frequencies to obtain survey data at a plurality of different frequencies. Moreover, the source electromagnetic signal can be emitted at a variety of frequencies, preferably between 0.01 Hz and 10 Hz. The method can be advantageously repeated over the same survey area using different frequencies of source electromagnetic signal. Lower frequencies are generally preferred. By probing the subterranean strata at a number of different frequencies of source electromagnetic signal, it is possible to obtain improved vertical resolution of structures within the subterranean strata configuration.

The source signal can be from a horizontal electric dipole. Such a signal can be provided using existing equipment, and also allows relatively simple inversion modelling.

The invention also provides a method of analysing results from an electromagnetic survey of an area that is thought or known to contain a subterranean hydrocarbon reservoir, comprising: providing survey data indicative of phase difference between first and second components of a detector signal resolved along first and second directions respectively; extracting the phase differences from the survey data; and determining a metric from the phase differences that is predictive of the presence or absence of hydrocarbon.

The phase differences can be extracted by rotationally transforming the survey data from an instrument frame to a source frame.

The invention also provides a computer program product bearing machine readable instructions for implementing the analysis method.

The invention further provides a method of planning an electromagnetic survey of an area that is thought or known to contain a subterranean hydrocarbon reservoir, comprising: creating a model of the area to be surveyed including a seafloor,

a rock formation containing a postulated hydrocarbon reservoir beneath the seafloor, and a body of water above the seafloor; setting values for depth below the seafloor of the postulated hydrocarbon reservoir and resistivity structure of the rock formation; performing a simulation of an electromagnetic survey in the model; and obtaining from the model phase differences between first and second components of a detector signal resolved along first and second directions respectively.

Repeated simulations for a number of distances between a source and a detector and frequencies can be performed in order to allow optimum surveying conditions in terms of source-to-detector distance and frequency of EM signal for probing the hydrocarbon reservoir to be selected when performing an electromagnetic survey. The effects of differing detectors array configurations and source tow paths can also be modelled.

The invention also provides a computer program product bearing machine readable instructions for implementing the planning method.

[9] WO 02/14906 A1

[10] MacGregor, L.M., Constable, S.C. & Sinha, M.C. The RAMESSES experiment III: Controlled source electromagnetic sounding of the Reykjanes Ridge at 57° 45' N. *Geophysical Journal International*, **135**, 1998, 773-789.

[11] Chave, A.D. & Cox, C.S., Controlled electromagnetic sources for measuring electrical conductivity beneath the oceans, 1. Forward problem and model study. *J. Geophys. Res.*, **87**, 1982, 5327 – 5338

[12] Martin C. Sinha, "Controlled source EM sounding: Survey design considerations for hydrocarbon applications", *LITHOS Science Report April 1999, 1, 95-101*

[13] GB 2382875 A

[14] WO 01/20366 A1

[15] US 6,163,155

CLAIMS

1. An electromagnetic survey method for surveying an area that is thought or is known to contain a subterranean hydrocarbon reservoir, comprising:

transmitting a source electromagnetic signal from a source location;

detecting a detector signal at a detector location in response thereto;

obtaining survey data indicative of phase difference between first and second components of the detector signal resolved along first and second directions respectively; and

forming the phase difference between the first and second components.

2. The survey method of claim 1, wherein the first and second components are radial and azimuthal with reference to the source location-receiver location geometry.

3. The survey method of claim 1, wherein the first and second components are vertical and azimuthal with reference to the source location-receiver location geometry.

4. The survey method of claim 1, wherein the first and second components are vertical and radial with reference to the source location-receiver location geometry.

5. The survey method of claim 1, further comprising obtaining survey data indicative of phase of a third component of the detector signal resolved along a third direction orthogonal to the first and second directions.

6. The survey method of claim 5, wherein the first and second and third components are vertical, radial and azimuthal with reference to the source location-receiver location geometry.

7. The survey method of any one of the preceding claims, wherein the first and second directions are orthogonal.

8. The survey method of any one of claims 1 to 7, wherein the source electromagnetic signal is broadcast from an antenna mounted on a submersible vehicle which is towed over the survey area to move the source location.

9. The survey method of any one of claims 1 to 7, wherein the source location is fixed.

10. The survey method of any one of the preceding claims, wherein the source electromagnetic signal is emitted at different frequencies to obtain survey data at a plurality of different frequencies.

11. The survey method of any one of the preceding claims, wherein the source electromagnetic signal is emitted at a frequency of between 0.01 Hz and 10 Hz.

12. A method of analysing results from an electromagnetic survey of an area that is thought or known to contain a subterranean hydrocarbon reservoir, comprising:

providing survey data indicative of phase difference between first and second components of a detector signal resolved along first and second directions respectively.

extracting the phase differences from the survey data; and

determining a metric from the phase differences that is predictive of the presence or absence of hydrocarbon.

13. The analysis method of claim 12, wherein the first and second components are radial and azimuthal with reference to the source location-receiver location geometry.

14. The analysis method of claim 12, wherein the first and second components are vertical and azimuthal with reference to the source location-receiver location geometry.

15. The analysis method of claim 12, wherein the first and second components are vertical and radial with reference to the source location-receiver location geometry.

16. The analysis method of claim 12, further comprising obtaining survey data indicative of phase of a third component of the detector signal resolved along a third direction orthogonal to the first and second directions.

17. The analysis method of claim 16, wherein the first and second and third components are vertical, radial and azimuthal with reference to the source location-receiver location geometry.

18. The analysis method of any one of claims 12 to 17, wherein the first and second directions are orthogonal.

19. The analysis method of claim 18, wherein the phase differences are extracted by rotationally transforming the survey data from an instrument frame to a source frame.

20. A computer program product bearing machine readable instructions for implementing the method of any one of claims 12 to 19.

21. A method of planning an electromagnetic survey of an area that is thought or known to contain a subterranean hydrocarbon reservoir, comprising:

creating a model of the area to be surveyed including a seafloor, a rock formation containing a postulated hydrocarbon reservoir beneath the seafloor, and a body of water above the seafloor;

setting values for depth below the seafloor of the postulated hydrocarbon reservoir and resistivity structure of the rock formation;

performing a simulation of an electromagnetic survey in the model; and obtaining from the model phase differences between first and second components of a detector signal resolved along first and second directions respectively.

22. The planning method of claim 21, wherein the first and second components are two of radial, vertical and azimuthal with reference to the source location-receiver location geometry.

23. The planning method of claim 21 or 22, further comprising:

repeating the simulation for a number of distances between a source and a detector and frequencies in order to select optimum surveying conditions in terms of source-to-detector distance for probing the hydrocarbon reservoir.

24. A computer program product bearing machine readable instructions for implementing the planning method of claim 21, 22 or 23.